

CROSS SECTIONS FOR MULTISTEP DIRECT EMISSION IN NUCLEON-INDUCED REACTIONS

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The energy-weighted sum rules (EWSRs) and the folding integral of the Feshbach, Kerman and Koonin (FKK) theory, that provides the cross sections of the multistep direct (MSD) reaction, require as input well-defined collective, one-phonon and/or incoherent one-step particle-hole cross sections (1SD). Thus, the theory of FKK allows for only one-particle emission. However, in nucleon-induced reactions at incident energies higher than the particle binding energy the nucleus is likely to be excited to unbound particle-hole final states that require special attention. This is because the unbound particle gives rise to more complicated direct processes.

In order to take these processes into account the 1SD cross section is split into the $1SD_{bound}$ one to bound final states and the $1SD_{unbound}$ to unbound particle-hole final states. The $1SD_{bound}$ includes cross sections to collective vibrational as well as to bound particle-hole states, both satisfying the EWSRs. Only the $1SD_{bound}$ can be folded into the MSD cross sections of FKK. On the other hand, the unbound particle of the $1SD_{unbound}$ can either give rise to gradual absorption by undergoing damping into the quasi-bound states of the compound nucleus or escape the nucleus even after a few rescattering collisions, giving rise to a one-step or multistep two-particle emission. The former process dominates at lower energies and the latter above 40 MeV. Both processes go beyond the scope of FKK.

Using the non-normal DWBA matrix elements to describe the intermediate stages of the MSD reaction and allowing for all sequences of reaction stages that contribute to a MSD reaction, it is shown that the FKK MSD cross sections for one-particle emission together with the $1SD_{unbound}$ for the more complicated processes describe well the inclusive emission of nucleons in the incident energy range from 25 MeV to 120 MeV.